# Perceptions of the Nature of Science by Geoscience Students Experiencing Two Different Courses of Study

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## ABSTRACT

Student knowledge of the Nature of Science (NOS) is critical to their understanding of science. NOS encapsulates the tenets of how science is regarded and the heuristics by which science is judged to be valid and appropriate. The importance of NOS to science education has lead to curricular and policy development that mandate the construct be taught throughout the K-12 science curriculum. If this curriculum is effective there is an expectation that students would enter post-secondary with foundational knowledge of NOS. Our research examined the perspectives of NOS among two different cohorts of undergraduate geoscience students, one of lower division students beginning their study of geoscience and a second of upper division students nearing the completion of their degree. We assessed their intellectual and emotional perceptions of NOS at the beginning of the semester. At the end of the semester we again assessed their perceptions of NOS and their conceptual understanding of geoscience. Our results indicate there was not a significant difference between the two cohorts and there was a significant drop in the emotional perceptions of NOS over the semester ($p < .05$). Conceptual understanding of geoscience was found to be significantly correlated with emotional perceptions of NOS. The results, implications, and directions for future research are discussed.


## INTRODUCTION

An important part of studying science is having an understanding of how science takes place (National Research Council [NRC], 1996). The societal and scientific community norms and assumptions that regulate the processes, limitations, outcomes, and interpretations of science that shape scientific knowledge, combine to form *Nature of Science* (Lederman, 1992; McComas, 1998, 2002: Meichtry, 1993; Settlage and Southerland, 2007). It has been argued that a fundamental understanding of Nature of Science (NOS) is critical to providing context to scientific endeavors and principles (Alters, 1997; McComas; National Academy of Sciences [NAS], 1998; NRC, 1996). This suggests that rudimentary (or perhaps greater) understanding of NOS is essential to bringing accurate meaning to scientific ideas, developments, hypotheses, and theories.

The importance of NOS to learning about science is confirmed by the emphasis on the concepts in the *National Science Education Standards* (NRC, 1996), by the published position statement of the National Science Teachers Association (NSTA, 2000), and by the inclusion of NOS as a major theme in the *Benchmarks for Scientific Literacy* (American Association for the Advancement of Science [AAAS], 1993, 2009). Science education reform in the K-12 science curriculum to include NOS is anticipated to lead to increases in student understanding of the capabilities and limitations of science (Taber, 2008). Due to the complexity of NOS it is not uncommon for students to have limited understanding of the concepts or develop and express misconceptions related to NOS even as college graduates (Abell and Smith, 1994; Abd-El-Khalick, 2006; McComas, 1998). Yet, the work of Ryder and colleagues (1999) indicates that after 5-8 months of science experiences undergraduate students can express growth in their perceptions of NOS. The lack of consistency in reports on the impact of college level coursework on student development of perceptions of NOS provide justification for continuing to investigate the influence of the curriculum on student understanding of NOS. Further, increased attention toward developing student understanding of NOS and curriculum reform efforts designed to increase students' understanding of NOS provide justification for continuing research in this domain. The dynamic nature of educational norms requires us to continually gather empirical evidence to determine the current state of the system.

Given the inclusion of NOS content in reformed K-12 science learning standards for over ten years it is reasonable to expect undergraduate students entering college straight from high school to understand NOS concepts. Although prior research may provide contradictory evidence (Abd-El-Khalick, 2006), the implementation of reform efforts are promoted with the anticipation that such conditions will shift with time. Further, there is face validity and empirical support for the perception that science course work (Ryder et al., 1999), work with professional scientists (Bell, Blair, Crawford & Lederman, 2003), and a greater understanding of science content (Bell, Lederman, and Abd-El-Khalick, 2000) can influence perceptions and understanding of NOS.

The potential and anticipated influence of science coursework on perceptions of NOS led us to ask how familiar post-secondary geoscience students were with NOS and if there were detectable differences in their understanding based on the amount of college level science coursework they have experienced. Additionally, we wondered how the curricular content and instructional methods used in college level geoscience courses might influence students' levels of understanding and perceptions of NOS. Although other research has examined perceptions of NOS among similar populations of undergraduate students (Libarkin, 2001), we maintain reform efforts in science education and the dynamic nature of student populations provide warrant to continue investigating student perceptions and understanding of NOS. Such research contributes to the data documenting


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the levels of students' understanding of NOS associated concepts, the dynamic nature of the levels of students' knowledge of the concept, and the influence of curriculum and coursework on their continued development of NOS perspectives and knowledge. We do not want to fall prey to the temptation to suggest once true always true, particularly for conditions associated with the dynamic system of education. Therefore, we maintain it is critical we continue to examine student understanding of NOS informed by the literature, but not prejudiced by prior results.

Our research is unique in that we assessed the understanding and perceptions of NOS among two different levels of undergraduate Geoscience students. The first group was drawn from lower division undergraduate students enrolled in an introductory Geoscience course with an integrated inquiry component that engaged them in open-ended laboratory and field explorations. The second group was drawn from upper division undergraduate (or first year graduate) students enrolled in upper division lecture courses that emphasized applying text book and lecture knowledge learned to solving geochemical problems. Data collection was repeated at each level for a second year, with new groups of students, to increase our statistical power. Our report follows our review of literature pertinent to our study.

## DEFINING AND ASSESSING THE NATURE OF SCIENCE

Assessing students' understanding of NOS is challenged by the complexity of the construct. Nature of Science is a multifaceted construct with elements that include aspects of scientific practice, scientific knowledge, and the human influence on scientific developments and transformations (Abd-El-Khalick and Lederman, 2000b; Alters, 1997; Driver, Leach, Millar, and Scott, 1996; Kimball, 1967; Lederman, 1992; McComas, 1998; Meichtry, 1993; NSTA, 2000; Settlage and Southerland, 2007). Due to the complexity of NOS there are multiple perspectives that have been used to define the construct. Therefore, we provide an operational definition of NOS to clarify the perspective we are using in our research. We contend that the basic tenets of NOS that should be included in a definition of the construct are:

- Science is both reliable and tentative;
- Science is not guided by a single scientific method, but by multiple methods of science, such as observation, experimentation, inference, and logical argument;
- The steps and processes of science are not a linear lock-step progression but rather a more dynamic system that involves multiple interactions and directions;
- Science is based on the natural world, and does not rely on supernatural elements for empirical data;
- The definitions of the vocabulary associated with scientific knowledge structures may be divergent from the definitions of the same words used in everyday conversation;
- Science is a human endeavor, culturally bound, and subject to bias;
- Peer review and replication are used to maintain integrity and precision;
- Science is not democratic, but instead self correcting with empirical evidence and logic superseding authority.

The complexity of NOS has complicated the development of valid and reliable instruments (Lederman, Wade & Bell, 1998) particularly instruments that can be used to rapidly assess student knowledge of the construct, provide quantitative data, and be efficiently implemented to assess larger samples. Although several instruments have been created and used to research perceptions of NOS (Aikenhead, Ryan, & Fleming, 1989; Good, Cummins, and Lyon, 1999; Kimball, 1968; Leaderman, Abd-El-Khalick, Bell, and Schwartz, 2002: Liang et al, 2008; Moore & Foy, 1996) they tend to be time consuming for participants to complete, require participants to have well developed reading and writing skills, and can be cumbersome to score or interpret especially in research situations which investigate large samples.

The assessment of student perceptions of NOS is further complicated by the notion that NOS may be contextual and domain dependent which suggests that the teaching and learning of NOS may take different forms depending on the situation and instructional goals (Cobern, 2000; Irwin, 2000; McComas, 1998; Schwartz, Lederman, and Crawford, 2004). Thus, the instruments used to measure student perceptions of NOS need to be selected based on the context in which they are being used, the research questions the data will address, and the methods used for investigation.

Responding to the parameters involved in assessing NOS we sought an instrument that allowed us to generalize our findings, that was relevant to a range of learning contexts, structured to provide quantitative data, and scored quickly and consistently since our sample size was fairly large. We found that the Science Attitude Inventory II [SAI II] (Moore and Foy, 1996), a 40 item tool that uses responses on a five point Likert scale to assess NOS intellectual knowledge and attitudes toward science, met our criteria. Although the SAI II has been critically reviewed (Lichtenstein et. al, 2008) it does measure perceptions of the primary tenets of NOS. Further, the data used by Lichtenstein and colleagues in their factor analysis examination of the SAI II were collected from a convenience sample of 12 to 14 year old students, a very different population than the college science students used in our study.

The study by Lichtenstein et al. (2008) indicates that the SAI II is most likely unreliable for use with early adolescents. However, their research lacks evidence to indicate the instrument is unreliable with more mature or experienced populations. The differential perception of NOS by different populations is an additional consideration when assessing perceptions and understanding of the construct (Palmquist and Finley, 1997; Ryder et al., 1999) particularly engagement in scientific activities. The association between instrument effectiveness and the research population on which the psychometric analysis was conducted is a critical

consideration when contemplating the use of a tool in research. We argue that the lack of empirical support for the unreliability of the SAI II with college students and the probability that the instrument will perform differently with these populations provides justification for using the instrument in our study. Although the criticism of the SAI II and other NOS scales does suggest that data collected using these instruments should be considered with caution, the lack of alternative solutions (meeting our data collection criteria) leaves us constrained to choose among the existing tools, such as the SAI II, that have been effectively applied in research (Barnet, 2004; Liang, 2002; Nadelson, 2007; Ramsey, Walczyk, Deese, and Eddy 2000; Sorge, Newsom, and Hagerty, 2000; Way, 2009).

## TEACHING TO INCREASE STUDENT UNDERSTANDING OF NOS

There is an expectation that professional scientists understand and conform to nature of science (Alters, 1997; Kuhn, 1970; McComas, 1998), which may develop with experience and education. The challenge associated with developing an understanding of NOS calls for science curriculum and instruction specifically structured to achieve this goal. For example, increases in student NOS understanding have been accomplished using practices such as explicit instruction, time for reflection, facilitated reflection, and placing NOS into context by integrating the construct as part of the science curriculum (Abd-El-Khalick and Lederman, 2000b; Gess-Newsome, 2002; Scharmann, Smith, James, and Jensen, 2005). These instructional approaches are similar to those recommended when teaching for conceptual change (Dole & Sinatra, 1998; Sinatra and Pintrich, 2003). It may be possible for students to gain understanding of NOS through implicit exposure to the construct when engaging in scientific activities, such as participating in research and reading scientific reports (Palmquist and Finley, 1997; Ryder et al., 1999). However, our position is more closely aligned with the research that indicates that context should be established when teaching NOS, exposure should be explicit, and reflection is encouraged and facilitated (Abd-El-Khalick, 2006; Abd-El-Khalick and Lederman, 2000b; Leaderman 1999). Even so, it is likely that instructional methods used to explicitly expose students to NOS will have varying impact on their NOS knowledge, particularly if there are variations in the contexts of the presentation and the science content knowledge of the students. The potential for variations in the instructional and curricular impact on student development of NOS understanding and likely connection to student science content knowledge provides justification for continuing to examine how science courses influence student understanding of NOS.

Many instructional and curricular approaches to teaching NOS have been implemented and investigated for effectiveness. Scharmann and colleagues (2005) advocated the use of analogy using the concept of "*umbrellaology*" to teach NOS to prepare students for understanding of the difference between evolution and intelligent design. Khishfe and Lederman (2006) report two approaches to teaching NOS, one in which they taught NOS using an integrated approach in environmental science, and another in which they taught NOS using a set of activities that addressed related issues. Their results indicate that both approaches produced increases in students' knowledge of NOS and that one method was not more effective than the other. Hanuscin and colleagues (2006) report using explicit and reflective instruction techniques to increase preservice teachers' and undergraduate teaching assistants' understanding of NOS. Abd-El-Khalick and Lederman (2000a) explored the influence of the integration of the history of science on student development of nature of science views. Their results indicate courses in the history of science may not be an effective means of teaching NOS unless NOS is explicitly addressed and students hold some prior knowledge of NOS. In yet another instructional approach Akerson and colleagues (2007) integrated inquiry and explicit reflective instruction to teach NOS content to elementary school teachers. Their results indicate there were positive changes in the teachers' views of the nature of science.

The range of methods for teaching NOS and the corresponding variety of targeted populations reflect the complexity to finding an effective instruction and curricular solution for increasing student understanding of and reasoning with NOS. The ongoing development and investigation of approaches to NOS instruction and the differential reaction by the study populations being examined provide justification for continued exploration in this area of science education.

## ATTITUDES AND EMOTIONAL PERSPECTIVES OF SCIENCE

Closely related to understanding or perceptions of NOS is attitudes or emotional perspectives of science (Aikenhead, Ryan, and Fleming, 1989). Research on attitudes toward science has revealed a link with student achievement in science (Papanastasiou and Zembylas, 2004; Tuan, Chin, Shieh, 2005). Further, research has also exposed associations between attitude toward science and knowledge of science (Bak, 2001). The connection between knowledge of science, performance in science, and attitudes toward science make evident the value of assessing students' attitudes or emotions toward science when examining their understanding of NOS.

In their review of literature on attitudes toward science Osborne and colleagues (2003) explore the definition of the construct, the relationship between individual characteristics (age, coursework, years of higher education) and attitudes toward science, and the challenges associated with measuring the construct. They preface their definition with a statement regarding the complexity and nebulous nature of the construct, which they follow with an explanation of attitudes toward science as the affective actions toward or perceptions of science. The challenges associated with defining attitudes toward science are manifested in attempts to measure the construct. In efforts to address the conundrum it has been recommended that measures of attitudes toward science assess students' feelings, emotions, and beliefs about the construct (Kind, Jones, & Barmby, 2007) and research on

attitudes toward science should also take personal variables into consideration (Osborne et al., 2003).

An examination of the SAI II emotions subscale items reveals content specifically related to affective perceptions of science. Collectively, the items assess the range of affective perceptions of science called for by Kind and colleagues (2007) which provides the rationale for using the SAI II to assess students' emotions toward science.

## OUR STUDY

Our research goals were to determine the intellectual and emotional perceptions of NOS of college students enrolled in lower and upper division geosciences courses. Further, we wanted to know if the levels changed over the course of a semester and how the intellectual perceptions and emotions toward NOS might be related to personal variables and conceptual knowledge of geoscience. We wanted to examine two different levels of geosciences courses (lower and upper division undergraduate) that were taught using two different instructional approaches, The lower division sophomore-level geosciences course had integrated lab and field experiences designed to promote student engagement in inquiry while the upper division undergraduate capstone geochemistry courses were lecture based. We wanted to determine if the contrasting instruction and difference in curriculum would lead to differential understanding of NOS and attitudes toward science. We also selected these courses to investigate because of importance to the curriculum.

### Study Questions

We used these three questions to guide our research:

*What were the perceived levels of NOS intellectual understanding and emotions toward science of the students enrolled in the two different levels of a geosciences curriculum?*

*Did the participants' levels of NOS intellectual understanding and emotions toward science correspond to their age, years of college, number of science courses or accurate conceptual understanding of geoscience?*

*Did the participants' intellectual and emotional perceptions of NOS change over the course of a semester and was the outcome consistent between the student groups?*

Given the complexity of NOS we stated our questions to reflect a more tentative interpretation of our data using the phrase "*perceptions of NOS*" as we only measured their perspectives and did not assess their application of NOS.

## METHOD

### Participants

Our study began with recruiting the lower and upper division undergraduate geoscience students from a university in the western Unites States which enrolls approximately 20,000 students. We identified several lower division undergraduate geoscience courses in which the enrolled students had limited knowledge of science because they had taken few college level science courses. Similarly, we identified several upper division undergraduate geoscience courses in which the enrolled students were anticipated to have high levels of science knowledge because they had taken multiple college level science courses. Based on our study goals we then targeted a lower division undergraduate inquiry based advanced introductory geosciences course and two upper division capstone courses in geochemistry that sometimes enroll first-year masters students. Following a commitment for cooperation by faculty in the Geosciences Department we recruited the students enrolled in these courses to participate in our study. We repeated our recruitment and data collection a year later with a new cadre of students to increase our sample size and the corresponding statistical power.

In our first year of data collection we recruited 26 lower division participants from the advanced introductory geoscience course and 33 participants from the same course in year two. We were able to link the pre and post-tests from 24 participants from year one and 27 from the year two group. This gave us a total of 51 lower division students.

To complete our sample we recruited 23 participants from the upper division courses in year one and 9 participants from year two. Again, we limited our analysis to the participants who completed both the pre and post tests, which resulted in 20 from year one and all 9 from year two. This resulted in a total of 29 upper division student participants.

We selected to limit our demographics measures to age, gender, number of years in college, number of college level science courses, and academic major, for two reasons. First, our IRB guidelines required gathered demographics to minimize the potential for the identification of specific individuals, which constrained the range of personal information data that we could ethically collect. Second, in our arrangement with the cooperating geoscience faculty we agreed to limit our data collection to minimize the time required for students to complete our surveys. Our participants' demographic data are presented by division level in Table 1.

### Procedures and Materials

In both years we gathered data on intellectual perceptions of NOS and emotions toward science at the beginning of the semester prior to instruction and at the end of the semester after students had nearly completed their course of study. We gathered their conceptions of

**TABLE 1. DEMOGRAPHICS OF THE LOWER AND UPPER DIVISION STUDENTS**

| Measure | Lower Division Undergraduate Students | Upper Division Students |
|---|---|---|
| N | 51 | 29 |
| Age | *M* = 25.25 (*SD*[1] = 5.94) | *M* = 31.1 (*SD* = 9.72) |
| Sex (M/F) | 28 / 23 | 17 / 12 |
| Yrs of College | *M* = 3.38 (*SD* = 1.76) | *M* = 5.7 (*SD* = 2.48) |
| Number Science Courses | *M* = 6.29 (*SD* = 3.97) | *M* = 16.85 (*SD* = 11.09) |

[1] standard deviation

geoscience only at the end of the semester. To assure we would be able to match our measures we requested the participants to use the last five digits of their phone number (or one that they would readily recall) as a unique code on all instruments. Even though we recommended the participants write their code down, we anticipated a small percentage of students would not recall their code at post testing and, therefore, we gathered our demographic data again at post-testing. We expected to be able to match pre and post data based on demographics for those participants who did not use the same code at pre and post testing. However, even with the second round of demographics in the data collection we still had pre and post surveys that we could not link and therefore did not include these data in our analysis.

## The Geoscience Courses

*The Lower Division Course* - The lower division course was a 200-level course for geoscience majors that is designed around a theme, the geological evolution of western North America. The study of this theme serves as a means of introduction to the nature of scientific investigation, and the specific disciplines and research methods geologists apply to formulate and test hypotheses. At least one lecture and in-class activity are used to explicitly discuss the scientific method as used by geoscientists, and this method is practiced during the semester through field and lab exercises. Early labs focus on building observational skills while later labs ask students to form questions into hypotheses, some of which are tested experimentally by the group. A mapping project that takes approximately half of the semester is explicitly linked with the practice of making observations, framing questions, hypothesis building and testing. Lectures use a historical approach to illustrate the building of geologic knowledge, and draw from the primary scientific literature.

*The Upper Division Course* - The upper division courses were two equivalent 400-level courses in geochemistry, one for students studying hydrology, and one for students studying geology. These courses were designed to provide a quantitative examination of the application of chemical principles to the study of Earth materials and processes. Instruction in these courses was lecture and text book based. Additional instructional approaches included reading and discussing the primary literature and extensive application of geochemical principles learned through written problem sets.

## Assessing Intellectual and Emotional Perceptions of Nature of Science

We used the *Scientific Attitude Inventory II* (SAI II) instrument (Moore and Foy, 1997) to assess our participants' intellectual and emotional perceptions of nature of science. This 40 item instrument asks subjects to respond on a five point Likert scale (with "1" representing *strongly disagree* to "5" representing *strongly agree*) to statements such as "*Scientists believe that nothing is known to be true for sure*." Twenty four of the SAI II items assess intellectual perceptions of the basic tenets of NOS, such as science conclusions are tentative and science knowledge is subject to change. Sixteen additional items assess affective or emotional perceptions of science. The affective items ask subjects to respond to statements such as, *"I would like to work with other scientists to solve scientific problems."* The SAI II uses a combination of 40 positive and reverse statement items to form two subscales, one assessing intellectual understanding of nature of science and the other assessing emotional perceptions toward nature of science. Given the five point Likert scale an average near 1.0 would be considered low understanding or negative emotional perspectives of NOS and an average near 5 would be considered high understanding or positive emotional perspectives of NOS. Likewise a mean near 3.0 would be representative of a neutral position on both subscales.

The reliability of this instrument was previously determined using split-half correlation which produced a value of 0.81, and the Cronbach's Alpha analysis produced a value of 0.78, when examined using over 500 high school age participants (Moore and Foy, 1997). Lichtenstein and colleagues (2008) maintain there are psychometric issues with the SAI II, and similar to Moore and Foy they conducted their research on the instrument using a convenience sample of 12-14 year old students. As we have previously discussed perceptions of NOS are experience and knowledge dependent (Abd-El-Khalick, and Lederman, 2000b; Bell, Blair, Crawford, and Lederman, 2003). Therefore, there is justification for assuming the performance of the SAI II would be significantly different with college students, particularly those who are declared science majors. The average age of our participants was 27.9 years and they had an average of 11.09 college level science courses which we contend influenced their capacity to respond to the SAI II items from an informed perspective.

We gathered data using the SAI II at the beginning of the semester prior to instruction and again at the end of instruction after the semester course of study. We gathered data using paper forms of the instrument and used statistical software for coding, scoring, and analysis.

## Assessing Conceptual Understanding of Geoscience

We utilized the *Geosciences Concept Inventory* (Libarkin and Anderson, 2005) to assess our participants' conceptual understanding of geosciences. The *Geosciences Concept Inventory* (GCI) is designed to provide researchers the capacity to create custom instruments to meet their investigative agendas. Researchers can select from over 70 validated items in the GCI data base to create a customized conceptual inventory instrument to assess participants' conceptual understanding of a wide range of geosciences concepts. The validity of the items is established based on the expert feedback from the professional geoscience education community. Our assessment was composed of nineteen items selected from the GCI database. We selected items representative of the fundamental knowledge anticipated to be acquired by students completing the advanced introductory course in geosciences and assumed to be mastered by students enrolled in upper division undergraduate geosciences coursework.

The GCI is scored based on the correct response to the items, with composite scores formed out of the total number of correct responses. The GCI contains a mixture of items that have a single correct answer and items that necessitate subjects to select a combination of alternatives. The GCI scoring guide indicates that all correct answers have to be selected in order for the item to be considered correct, there is no partial credit for the items (Libarkin and Anderson, 2005).

We decided to administer the instrument only at the end of the course at the same time we post-tested using the SAI II because we anticipated that a GCI pretest of the lower division students would indicate that they held low conceptual understanding of geosciences, which would have been consistent with where they were in their coursework. Low pretest scores could have potentially skewed our data influencing the ability to conduct analysis based on fundamental assumptions of data structures. Further, our intention for administering the GCI was not to examine our participants' change in conceptual understanding of geosciences. Our goal was to use the GCI to collect data at the end of the course to determine how conceptual understanding was related to perceptions of NOS.

## RESULTS

We began our analysis by scoring the instruments accordingly, reverse coding the item responses as necessary. We then calculated the reliability of the SAI II and the GCI. Our reliability analysis of the SAI II revealed a Cronbach's alpha of .83 indicating a good level of instrument reliability in our application. Our test of internal reliability of the SAI II intellectual perceptions of science subscale produce a Cronbach's alpha of .69 and the emotional perceptions of science subscale produce a Cronbach's alpha of .79, both of which are considered to be within the range of acceptable reliability values (Gronlund, 1993). The reliability analysis of our derived version of the GCI revealed a Cronbach's alpha of .81 indicating a moderate to good level of instrument reliability. The outcome of our reliability analysis indicated we could proceed with the assumption that our instruments gathered reliable data. Our tests of data normality revealed insignificant values for the kurtosis and skewness statistics. These results allowed us to proceed assuming our data were normally distributed.

### Intellectual and Emotional Perceptions of NOS

Our first research question asked: *What were the perceived levels of NOS understanding and attitude toward science of the participants enrolled in the two different levels of a geosciences curriculum?* To answer this question we scored the pre-course SAI II outcomes according to Moore and Foy (1997) forming an overall composite value for the items as a whole and for the two subscales, intellectual understanding of the nature of science and the emotional perceptions of science. We then standardized these composite scores based on the instrument's five point Likert scale (see Table 2).

We used the scoring results from the instrument validation study to interpret our results (Moore and Foy, 1997). The interpretation of the results for both levels of geosciences students suggests their perspectives for intellectual and emotional perspectives of NOS are in the moderately positive range.

### NOS Relationship to Personal Variable and GCI Scores

Our second research question asked: *Did the participants' perceived levels of NOS intellectual understanding and attitude correspond to their age, years of college, number of science courses or accurate conceptual understanding of geoscience?* We began our analysis of this question by scoring the participants' achievement on our GCI. Scoring of the GCI is based on the number of items correct, therefore, for our application the participants' scores could have ranged between zero and nineteen. Following the GCI scoring we conducted a correlational analysis using age, years of college, number of science courses, GCI scores, and post-test intellectual understanding and emotional perspectives of NOS as measured by the SAI II. The results of the correlation analysis are presented in Table 3.

Our analysis revealed conceptions of geoscience (as measured by the CGI) were not significantly correlated with participants' intellectual perceptions of NOS ($r$ = 0.20, $p$ = 0.09) but were significantly correlated with their emotional perspectives ($r$ = 0.26, $p$ < 0.05) of science (as measured by the SAI II). The relationship between geoscience conceptions and emotional perceptions of science is presented in Figure 1. In addition the participants' intellectual and emotional perceptions of NOS were also found to be significantly correlated ($r$ = 0.61, $p$ < 0.01). Consistent with prior research (Abd-El-

**TABLE 2. STUDENT SAI II SCORES FOR INTELLECTUAL, EMOTIONAL AND OVERALL PERCEPTIONS TOWARD NATURE OF SCIENCE COURSE LEVEL**

| Measure | Lower Division Geoscience Students (*N=51*) | | Upper Division Geoscience Student (*N=29*) | |
|---|---|---|---|---|
| | *Pre-Test* *M*[1] *SD*[2] | *Post Test* *M SD* | *Pre-Test* *M*[1] *SD*[2] | *Post Test* *M SD* |
| **Intellectual Subscale** | 3.73, 0.27 | 3.74, 0.29 | 3.67, 0.37 | 3.61, 0.30 |
| **Emotional Subscale** | 3.94, 0.30 | 3.85, 0.32 | 3.79, 0.41 | 3.65, 0.47 |
| **Overall Score** | 3.94, 0.24 | 3.90, 028 | 3.82, 0.38 | 3.72, 0.37 |

[1] 1 represents strong disagreement and 5 strong agreement;
[2] standard deviation.

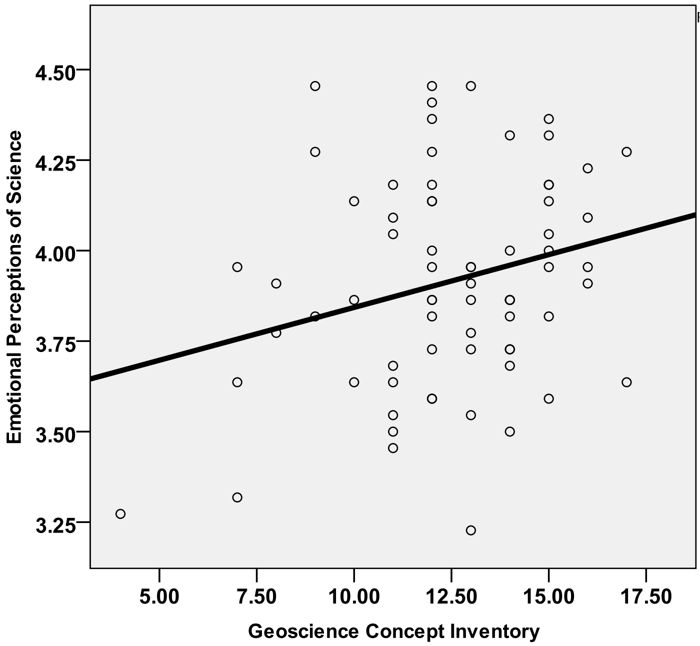


**FIGURE 1. Relationship between geoscience conceptions and emotional perceptions of science.**

Khalick, 2006) the number of science courses and years of college were not significantly correlated with participants' intellectual and emotional perceptions of NOS.

### Change in NOS over a Semester

Our third research question asked: *Did the participants' intellectual and emotional perceptions of NOS change over the course of a semester and was the outcome consistent between the student groups?* To answer this question we conducted a repeated measures ANOVA using class level (lower division or upper division) as the factor and the pre-test and post-test scores of intellectual perceptions of NOS, emotional perceptions of NOS, and the composite NOS scores (as measured by the SAI II) as the within subjects variables (Kutner, Nachtsheim, Neter,& Li, 2004). Our analysis revealed mixed results for time. For intellectual perceptions our results revealed a non-significant statistic of, $F(1,78) = 0.41$, $p > 0.05$, and for the composite NOS score a non-significant statistic of, $F(1,78) = 3.03$, $p > 0.05$. However, for the emotional perceptions of science our analysis revealed a significant statistics of $F(1,78) = 5.90$, $p < 0.02$, $\eta^2 = 0.07$. An examination of the means of emotional perceptions of science revealed the students had a significant drop from the beginning to the end of the semester. However, the intellectual perceptions of NOS and the composite scores for the SAI II did not change significantly with time. Graphic displays of the changes in scores are presented in Figure 2.

Further examination of the data by division level failed to reveal a differential change in perceptions of NOS. The lack of a differential change indicates that the students' perceptions of NOS were uniform regardless of whether they were enrolled in the upper or lower division courses. In other words, the students experienced the same pre to post variations in their NOS perspectives independent of course or division level.

## DISCUSSION

The goal of our research was to determine the state of nature of science knowledge of lower division and upper division geoscience students. Education is a dynamic system (Chen and Stroup, 1993) and we cannot assume what was true in the past remains true, especially in areas of reform that are receiving increased emphasis in the curriculum. Because of the recognition, attention, and implementation of NOS curriculum initiatives (AAAS, 1993, 2009; NRC, 1996; NSTA, 2000), there is justification to anticipate students who have recently graduated high school enter college with an understanding of NOS.

### Intellectual and Emotional Perceptions of NOS

Our results indicate that the lower division science majors participating in our study held the same level of intellectual and emotional perceptions of NOS as their upper division peers. Although it may be argued that neither group of students has grasped full NOS understanding (Abd-El-Khalick, 2006) it is also possible both have experienced growth in their NOS perceptions though education, but in different ways. Our interpretation of their scores indicated that both groups held moderately positive perceptions of NOS. This suggests that lower division students entering college are developing perspectives of NOS prior to entering the university, while their upper division peers further developed their perceptions while enrolled in their post-secondary science courses. Our explanation could also account for why the number of college level courses the

**TABLE 3. CORRELATIONS OF AGE, COURSES, GCI SCORES AND NOS PERCEPTIONS**

| Measure | Age | Years of College | Number of Science Courses | GCI Scores | NOS Intellectual Perceptions | NOS Emotional Perceptions |
|---|---|---|---|---|---|---|
| **Age** | ---- | 0.49** | 0.35** | 0.13 | 0.12 | 0.06 |
| **Years of College** | | ---- | 0.67** | 0.18 | 0.03 | -0.14 |
| **Num of Science Courses** | | | ---- | 0.37** | 0.09 | 0.07 |
| **GCI_SCORES** | | | | ---- | 0.20 | 0.26* |
| **NOS Intellectual Perception** | | | | | ---- | 0.61** |
| **NOS Emotional Perception** | | | | | | ---- |

* $p< 0.05$, ** $p < 0.01$

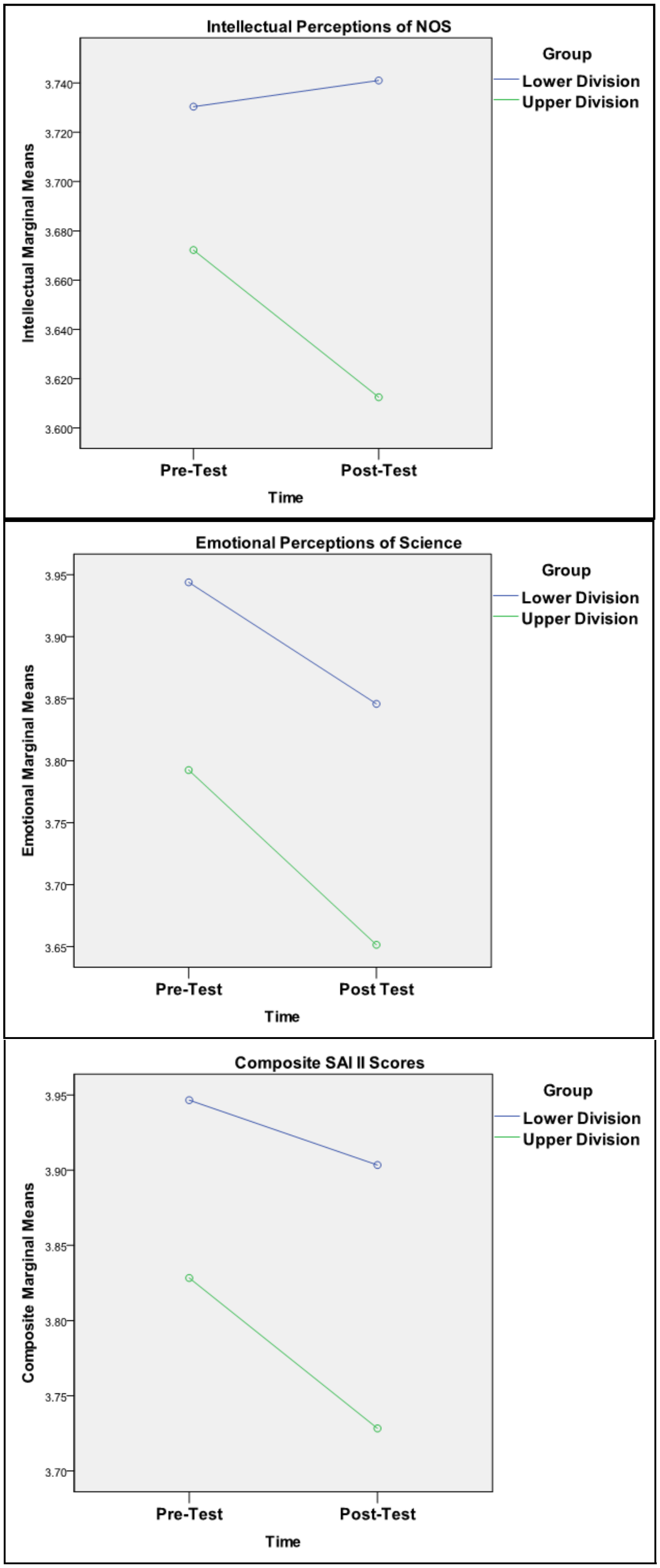


FIGURE 2. The plots of pre-test to post-test scores for SAI II intellectual subscale, emotions subscale and the composite scores for the entire instrument, for both lower and upper division participants.

participants had completed was not found to be correlated with NOS perceptions. Although more research needs to be conducted to determine how students are developing their NOS perspectives prior to entering post-secondary education, our results may provide some preliminary evidence that the K-12 NOS education initiatives (AAAS, 1993; NRC, 1996, NSTA, 2000) may be impacting student perceptions of NOS.

The notion that the lower and upper division students held approximately the same moderately positive intellectual and emotional perceptions of NOS, suggests that the approximately four years of college level science curriculum that the upper division students had taken did not substantially influence their intellectual and emotional perceptions of NOS. These results are consistent with the findings of Abd-El-Khalick (2006). The lack of a significant difference in the NOS views between the two levels of geoscience students suggests that NOS concepts are not likely being explicitly and reflectively taught in their post-secondary science curriculum. As noted previously, NOS curriculum is most effective when instruction is explicit and engages students in opportunities to reflect on NOS concepts (Abd-El-Khalick, 2006; Abd-El-Khalick and Lederman, 2000b; Leaderman, 1999). This is of particular importance in the domain of geosciences in which students typically engage in substantial field and laboratory work, which have been documented as mechanisms by which the development of NOS perceptions may be fostered (Palmquist and Finley, 1997; Ryder et al., 1999). Combining field and laboratory work with a conceptual change approach to instruction may result in substantial growth in NOS perceptions. Additional exploration of the long term influence of course integrated lab and field on NOS perceptions is warranted and an excellent direction for future research.

## NOS Relationship to Personal Variable and GCI Scores

The research on student intellectual understanding of NOS (Abd-El-Khalick, 2006) suggests that there is no relationship to personal variables. However, Osborne et al. (2003) report a link between personal variables and attitudes (beliefs and feelings) toward science. Therefore, we had anticipated that our participants' age, years of college, and the number of science courses would not be correlated with their intellectual perspectives of NOS but would be correlated with their emotional perspectives of NOS. Further, we had anticipated that additional science experiences would influence perspectives of NOS (Palmquist and Finley, 1997; Ryder et al., 1999). Our results revealed no significant relationships between NOS and our measured personal variables. The lack of relationship between NOS and the number of science courses or the amount of post-secondary education may be explained by the manner in which NOS is being taught – or assumed is being taught. It is possible that we may have encountered somewhat of a ceiling effect, and the differences due to experience or education were relatively slight and not detectable. Regardless, the notion that educational experience and the number of science courses are not related to views of NOS is a relationship in need of

further investigation. We posit that most university faculty would anticipate their curriculum would positively influence their students' NOS perceptions. However, since this does not seem to be the case, there is need to further investigate how university science faculty are addressing NOS content and the corresponding reactions of the students to the instruction.

The finding that our participants' emotional perceptions of science were significantly related to their conceptual understanding of geosciences as measured by the GCI suggests as students understand more they have a positive attitude toward science. In addition, the link between the emotional and intellectual perceptions of NOS, suggests that as understanding increases so do positive attitudes. This outcome provides evidence indicating that conceptual knowledge of geosciences is needed to increase geoscience students' affective perspectives of NOS. Further, the positive correlation between the number of science courses and conceptual understanding of geoscience suggests that conceptions develop with education. Interestingly, years of education was correlated with conceptual understanding which was correlated with emotional perceptions of NOS, but years of education was not directly correlated with perceptions of NOS. This suggests that increasing conceptual understanding of geoscience is more influential than science coursework on the development of perceptions of NOS. The determination of the links between emotions toward science, intellectual perceptions of NOS, and conceptual understanding should be explored in more depth and supported empirically, and therefore is an excellent topic for future investigations.

### Change in NOS over a Semester

We were encouraged to find that our participants' intellectual perceptions of NOS did not drop over the semester like their emotional perceptions of science. We did not detect a differential change in NOS perspectives between the lower and upper division students indicating a uniform drop in emotional perspectives of science regardless of level of study. We speculate the drop in emotional perceptions toward science resulted from an increase in the pressure to perform academically and the potential feelings of being overwhelmed prior to final exams at the end of the academic semester. It is also possible that the development of less positive emotions toward science reflects student development of cynicism toward science over the semester, particularly if they were not experiencing high levels of success in their science coursework. Similarly, the students may have been overconfident in their understanding of NOS at the beginning of the semester and less confident about their understanding at the end of the term. The shift toward more skeptical attitudes and perceptions of science in relationship to knowledge has been detected by Bauer and colleagues (2000). However, as Evans and Durant (1995) report, knowledge of science leads to more discriminating perspectives of science. Regardless, a significant drop in emotional perceptions toward science by science majors is of concern and warrants further investigation.

The stability of the intellectual perceptions of NOS is encouraging because of its link to emotions toward science. We posit that an increase in science knowledge may have offset potential drop due to decline in attitudes. Uncovering the source of the drop in emotional perceptions of science and the stable levels of intellectual perceptions of NOS over a semester and the potential influence of a conceptual change pedagogy are both excellent directions for future research.

## LIMITATIONS

There are several limitations to our research. Although we attempted to increase our statistical power with two semesters of data collection our sample size was still rather limited. A larger and perhaps more diverse sample may reveal a different outcome.

We used the GCI and SAI II for our data collection, both of which we established as having acceptable levels of reliability, but both have controversial levels of validity. The complexity associated with assessing NOS and conceptual understanding of geoscience may not be comprehensively captured by these instruments. Further, the data collected using these instruments was limited to quantitative data, which constrained our ability to determine why students responded as they did. A combination of interviews to gather qualitative data with the use of instruments to gather quantitative data may reveal a greater understanding of student responses and explanation of conditions.

Finally, our study sample was composed almost exclusively of undergraduate science majors. A sample drawn from a broader student population may reveal significant differences for measures such as educational levels and experience. Our future research will attend to these limitations as we attempt to unravel the relationships between students' coursework in undergraduate geoscience and their perceptions of nature of science.

## CONCLUSION

Student understanding and perceptions of NOS are fundamental to their learning science and becoming scientists (Alters, 1997; McComas, 2000; NAS, 1998; NRC, 1996). Several initiatives have been promoted as means of advancing student understanding and emotions toward NOS. As these initiatives and approaches become part of curriculum and instruction there is reason to suspect that there will be shifts in students' levels of NOS perceptions. Yet, our research suggests that our current approaches to teaching NOS are not positively influencing students' development of NOS perceptions. Further, the relation between student levels of science knowledge and their emotional perceptions of NOS and the relations between intellectual and emotional perceptions of NOS make student learning of science critical for enhancing their understanding of and attitude towards the tenets by which science operates. Our results provide evidence of the dynamic nature of student perceptions of NOS and the justification for continuing to pursue investigations of geoscience students' learning and perceptions of this construct.

## REFERENCES


Abd-El-Khalick, F. 2006. Over and over again: college students' views of nature of science. In: Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education, ed. L. B. Flick and N. G. Lederman, Dordrecht, The Netherlands, Kluwer Academic Publishers, 389–426

Abd-El-Khalick, F., and Lederman, N. G., 2000a, The influence of history of science courses on students' views of nature of science: Journal of Research in Science Teaching, v. 37, p. 1057-1095.

Abd-El-Khalick, F. and Lederman, N.G., 2000b. Improving science teachers' conceptions of the nature of science: A critical review of the literature. International Journal of Science Education, v. 22, p. 665–701.

Abell, S.K. and Smith, D.C., 1994, What is science? Preservice elementary teachers' conceptions of the nature of science. International Journal of Science Education, v. 16, no. 4, p. 475-487.

Aikenhead, G.S., Ryan, A.G., and Fleming, R.W., 1989. Views on science–technology– society (VOSTS). Saskatoon, Saskatchewan, Canada: Department of Curriculum Studies, College of Education, University of Saskatchewan.

Akerson, V. L., and Hanuscin, D. L., 2007, Teaching the nature of science through inquiry: Results of a 3-year professional development program: Journal of Research in Science Teaching, v. 44, p. 653-680.

Alters, B. J., 1997, Whose nature of science? Journal of Research in Science Teaching, v. 34, no. 1, p. 39-55.

Bak, Hee-Je, 2001, Education and public attitudes toward science: Implications for the "Deficit Model" of education and support for science and technology. Social Science Quarterly, v. 82, no. 4, p. 779-796.

Barnett, M., Strauss, E., Rosca, C., Langford, H., Chavez, D., and Deni, L., 2004, Improving urban youth's interest and engagement through field-based scientific investigations. In Y. B. Kafai, W. A. Sandoval, N. Enyedy, A. S. Nixon and F. Herrera (Eds.), Sixth International Conferences of the Learning Sciences Mahway, New Jersey, Lawrence Erlbaum, p. 73- 80.

Bauer, M. W., Petkova, K., and Boyadjieva, P., 2000, Public knowledge of and attitudes to science: Alternative measures that may end the 'Science Wars' Science, Technology, and Human Values v. 25, p.30–51.

Bell, R. L., Blair, L., Crawford, B., and Lederman, N. G., 2003, Just do it? Impact of a science apprenticeship program on students' understanding of the nature of science and scientific inquiry: Journal of Research in Science Teaching, v. 40, p. 487–509.

Bell, R. L., Lederman, N. G., and Abd-El-Khalick, F., 2000, Developing and acting upon one's conception of the nature of science: A follow-up study. Journal of Research in Science Teaching, v. 37, no. 6, p. 563–581.

Benchmarks for science literacy, American Association for the Advancement of Science., New York, 1993.

Benchmarks on-line: Benchmarks for science literacy, American Association for the Advancement of Science., New York, 2009. Retrieved April 2, 2009 from: http:// www.project2061.org/ publications/bsl/online/index.php?home=true

Chen, D., and Stroup, W., 1993, General system theory: Toward a conceptual framework for science and technology education for all. Journal of Science Education and Technology , v. **2**, p. 447-459

Cobern, W. W., 2000, The nature of science and the role of knowledge and belief: Science and Education, v. 9, p. 219-246.

Dole, J. A., and Sinatra, G. M., 1998, Reconceptualizing change in the cognitive construction of knowledge. Educational Psychologist, v. 33, no. 2/3, p. 109-128.

Driver, R., Leach, J., Millar, R., and Scott, P., 1996, Young peoples' images of science. Buckingham, UK, Open University Press.

Evans, G. and Durant, J., 1995, The relationship between knowledge and attitudes in the public understanding of science in Britain. Public Understanding of Science v. 4, p. 57 –74.

Gess-Newsome, J., 2002, The use and impact of explicit instruction about the nature of science and science inquiry in an elementary science methods course: Science and Education, v. 11, p. 55-67.

Good, R., Cummins, C.L., and Lyon, G., 1999, January, Nature-Of-Science Assessment Based On Benchmarks And Standards. Paper Presented At The Annual International Conference Of The Association For The Education Of Teachers In Science, Austin, Texas.

Gronlund, N.E., 1993, How to make achievement tests and assessments, (fifth ed).Boston, Allyn and Bacon.

Hanuscin, D. L., Akerson, V. L., and Phillipson-Mower, T., 2006, Integrating nature of science instruction into a physical science content course for preservice elementary teachers: NOS views of teaching assistants: Science Education, v. 90, p. 912-935.

Irwin, A., 2000, Historical case studies: teaching the nature of science in context. Science Education, v. 84 , p. 5-26.

Khishfe, R. and Lederman, N., 2006, Teaching nature of science within a controversial topic: Integrated versus nonintegrated: Journal of Research in Science Teaching, v. 43, p. 377-394.

Kimball, M. E., 1968, Understanding the nature of science: A comparison of scientists and science teachers. Journal of Research in Science Teaching, 5, p. 110–120.

Kuhn, T., 1970, The structure of scientific revolutions (2nd ed)., Chicago, University of Chicago Press.

Kutner, M. H., Nachtsheim, C. J., and Neter, J., 2004, Applied linear regression models (4th ed.), New York, McGraw-Hill.

Liang, L., Chen, S., Chen, X., Kaya, O., Adams, A., Macklin, M., et al., 2008, Assessing preservice elementary teachers views on the nature of scientific knowledge: A dual-response instrument. Asia-Pacific Forum on Science Learning and Teaching, v. 9, no. 1, article 1.

Lederman, N. G., 1992, Students' and teachers' conceptions of the nature of science: A review of the research. Journal of Research in Science Teaching, v. 29, no. 4, p. 331–359.

Lederman, N. G., 1999, Teachers' understanding of the nature of science and classroom practice: Factors that impede the relationship: Journal of Research in Science Teaching, v. 36, p. 916-929.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., and Schwartz, R. S., 2002, Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science: Journal of Research in Science Teaching, v. 39, p. 497–521.

Lederman, N. G., Wade, P. D., and Bell, R. L., 1998, Assessing the nature of science: What is the nature of our assessments: Science and Education, v. 7, p. 595-615.

Liang, Jia-Chi, 2002, Exploring scientific creativity of eleventh grade students in Taiwan. [Ph.D. thesis], University of Texas at Austin.

Libarkin, J.C., 2001, Development of an assessment of student conception of the nature of science: Journal of Geoscience Education, v. 49, p. 435-442.

Libarkin, J. C., and Anderson, S. W., 2005, Assessment of learning in entry-level geoscience courses: Results from the geoscience concept inventory: Journal of Geoscience Education, v. 53, p. 394-401.

Lichtenstein, M. J., Owen, S. V., Blalock, C. L., Yan, L., Ramirez, K. A., Pruski, L. A. , Marshall, C. E. and Toepperwein, M. A., 2008, Psychometric reevaluation of the scientific attitude inventory-revised SAI-II. Journal of Research in Science Teaching, v. 45, p. 600-616.

McComas, W. F., 1998, The nature of science in science education rationales and strategies. Dordrecht, The Netherlands, Kluwer Academic Publishers.

McComas, W.F., Clough, M.P.,and Almazroa, H., 2000, The role and character of the nature of science in science education. In W.F. McComas (Ed.), The nature of science in science education: Rationales and strategies (pp. 41–52), Dordrecht, The Netherlands, Kluwer.

Meichtry, Y. J., 1993, The impact of science curricula on student views about the nature of science. Journal of Research in Science Teaching, v. 30 no. 5, p. 429–443.

Nadelson, L. S., 2007, Preservice teachers' understanding of evolution, the nature of science, and situations of chance. [Ph.D. thesis, University of Nevada, Las Vegas.]

Teaching about evolution and the nature of science, 1998, National Research Council, Washington DC, National Academy Press.

National science education standards, 1998, National Research Council, Washington DC, National Academy Press.

An NSTA position statement: The nature of science 2000, National Science Teachers Association, Arlington, VA, NSTA.

Osborne, J., Simon, S. and Collins, S., 2003, Attitudes towards science: a review of the literature and its implications. International Journal of Science Education, v. 25, no. 9, p. 1049-1079.

Palmquist, B.C.,and Finley, F.N., 1997, Preservice teachers' views of the nature of science during a post baccalaureates science teaching program: Journal of Research in Science Teaching, v. 34, p. 595–615.

Papanastasiou, E. C. and Zembylas, M., 2004, Differential effects of science attitudes and science achievement in Australia, Cyprus, and the USA. International Journal of Science Education, v. 26, no. 3, p. 259-280.

Ramsey, L. L., Walczyk, J, Deese, W. C. and Eddy, D., 2000, Using demonstration assessments to improve learning. Journal of Chemical Education. v. 77, no. 11, p. 1511

Ryder, J., Leach, J., and Driver, R., 1999, Undergraduate science students' images of science. Journal of Research in Science Teaching, v. 36, no. 2, p. 201–220.

Scharmann, L. C., Smith, M. U., James, M. C., and Jensen, M., 2005, Explicit reflective nature of science instruction: Evolution, intelligent design, and umbrellaology: Journal of Science Teacher Education, v. 16, p. 27–41.

Sinatra, G.M. and Pintrich, P.R., 2003, Intentional conceptual change. Mahwah, NJ: Erlbaum.

Sorge, C.; Newsom, H., and Hagerty, J., 2000, Fun is not enough: Attitudes of Hispanic middle school students toward science and scientists. Hispanic Journal of Behavioral Sciences, v. 22, no. 3, p. 332-345.

Settlage, J. and Southerland, S., 2007, Teaching science to every child: Using culture as a starting point. New York, Routledge Press.

Taber, K. S., 2008, Towards a curricular model of the nature of science: Science and Education, v. 17, p. 179-218.

Tuan, H., Chin, C. and Shieh, S., 2005, The development of a questionnaire to measure students' motivation towards science learning. International Journal of Science Education, v. 27, no. 6, p. 639-654.

Way, J., 2009, How does a curriculum intervention that anchors instruction to the study of urban coyote behavior affect student learning? Electronic Journal of Science Education, v. 13, no. 1, p. 54-84.